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Cheng

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(54) **TRIODE**

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Sep. 30, 2013 (TW) .... 102135238 A

(51) **Int. Cl.**

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H01L 29/06	(2006.01)
H01L 29/73	(2006.01)
H01L 29/747	(2006.01)

(52) **U.S. Cl.**

CPC ***H01L 29/0607*** (2013.01); ***H01L 29/7302*** (2013.01); ***H01L 29/747*** (2013.01)

(58) **Field of Classification Search**

CPC . H01L 29/7455; H01L 29/744; H01L 29/749; H01L 29/7395; H01L 29/7397

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,717,241	A *	2/1998	Malhi et al.	257/378
2002/0158270	A1 *	10/2002	Yamamoto et al.	257/200
2013/0075866	A1 *	3/2013	Otake et al.	257/577

* cited by examiner

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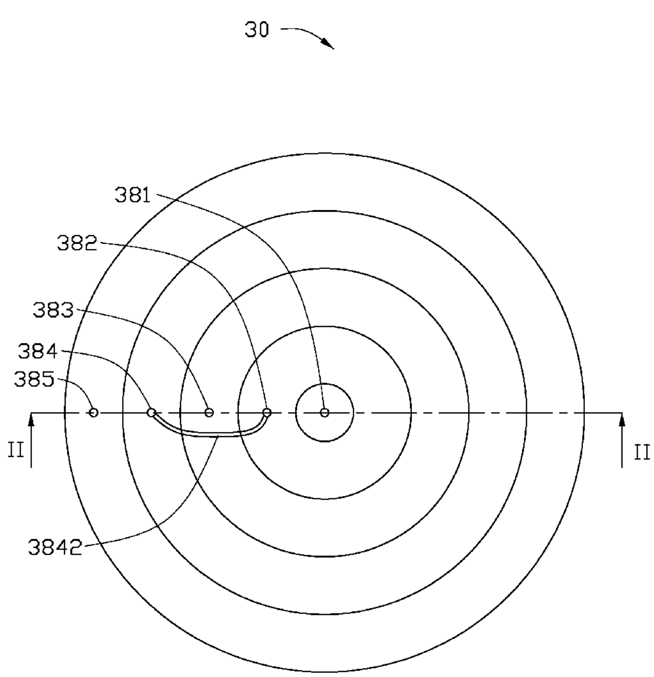
(57) **ABSTRACT**

A triode includes a semiconductor, a deep n-well, a p-well, an n+ doping region, and a doping region. The deep n-well is disposed adjacent to the semiconductor substrate. The p-well is included in the deep n-well and serves as a collector region of the triode. The n+ doping region serves as a base region of the triode. The p+ doping region serves as an emitter region of the triode. The deep n-well is coupled to the n+ doping region via at least one conducting channel.

7 Claims, 11 Drawing Sheets



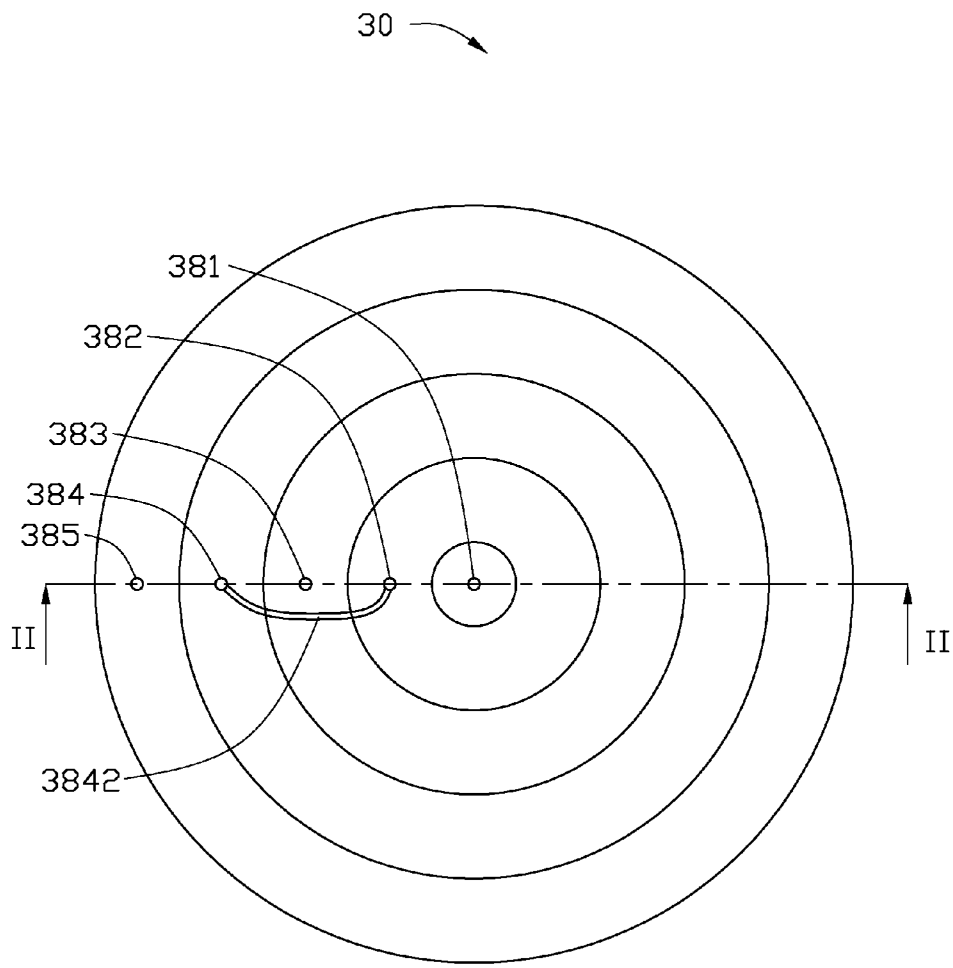


FIG. 1

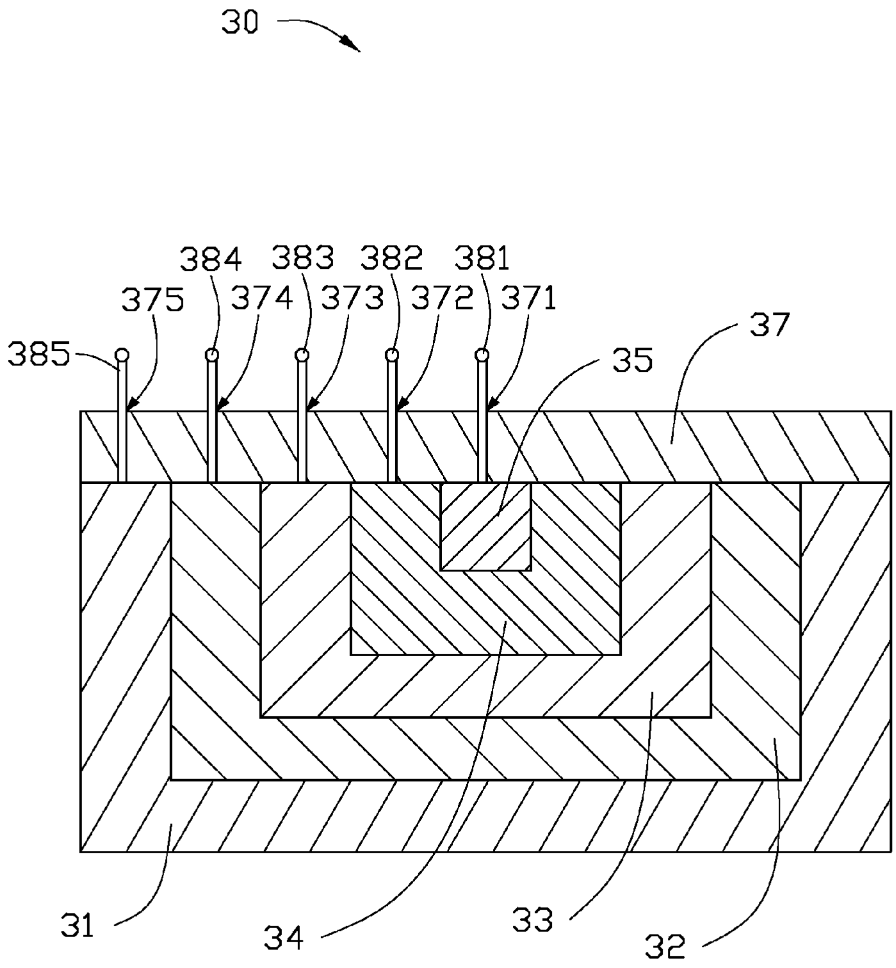


FIG. 2

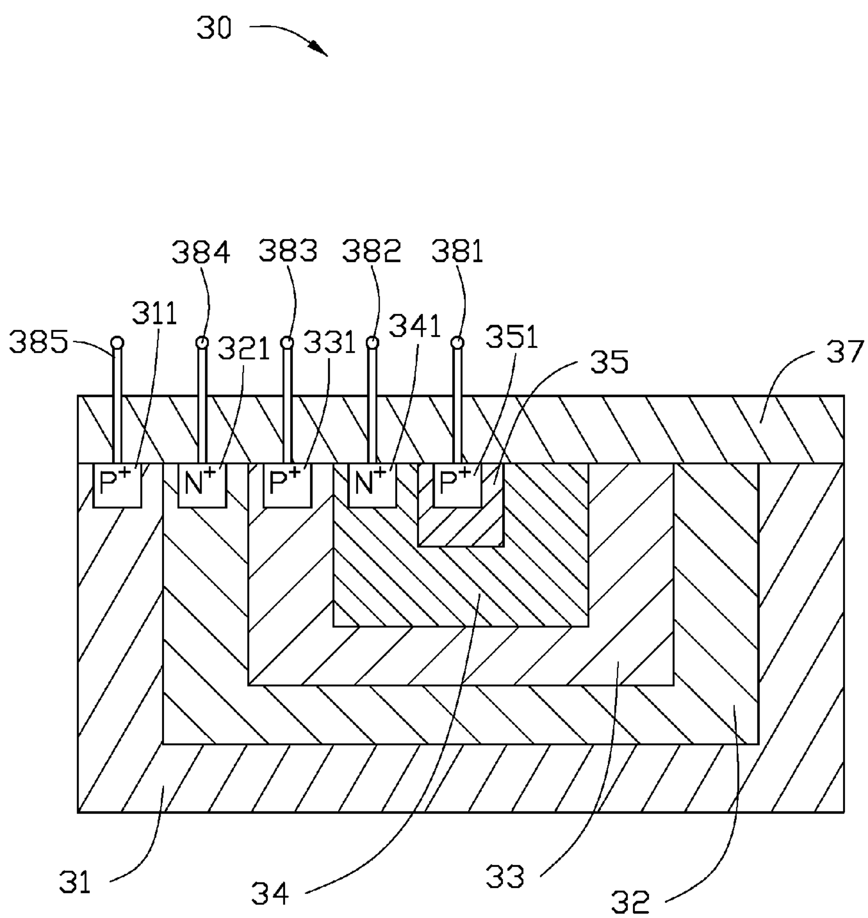


FIG. 3

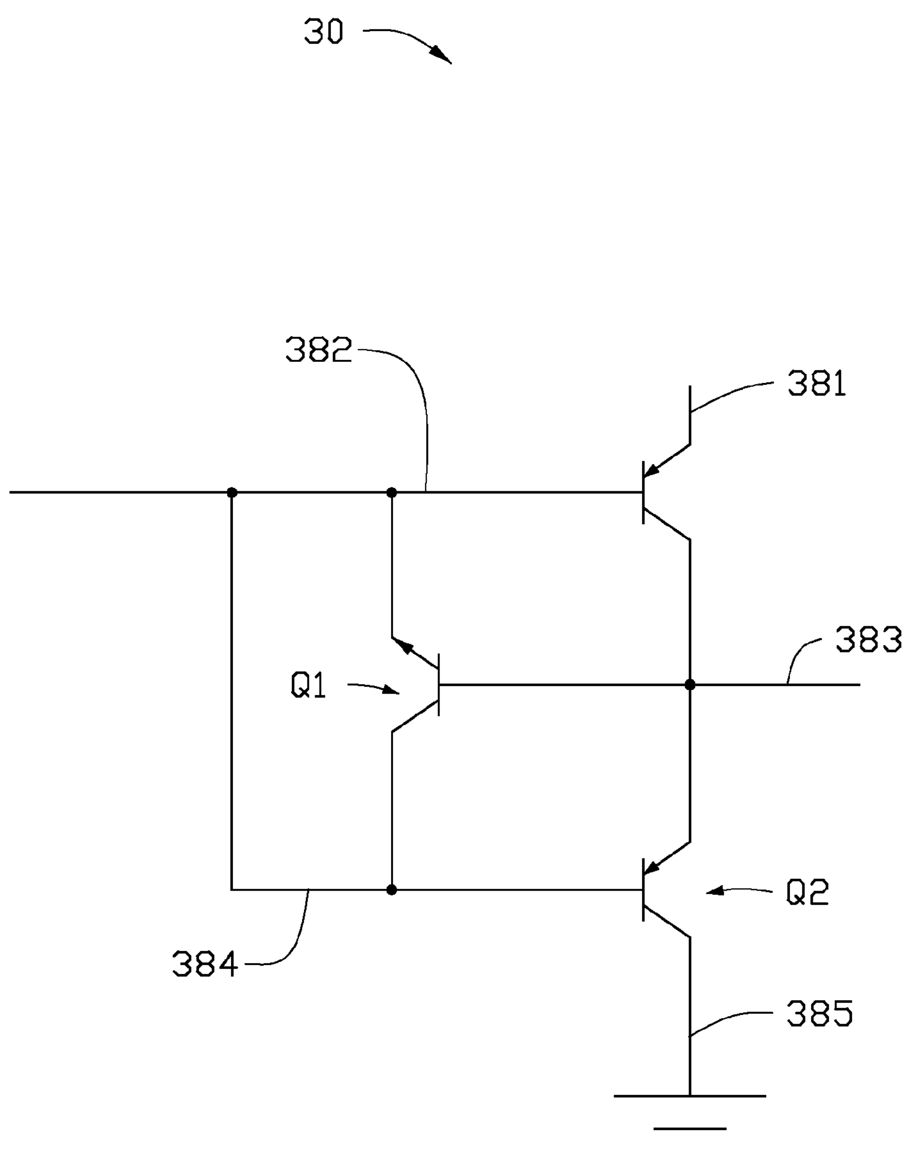


FIG. 4

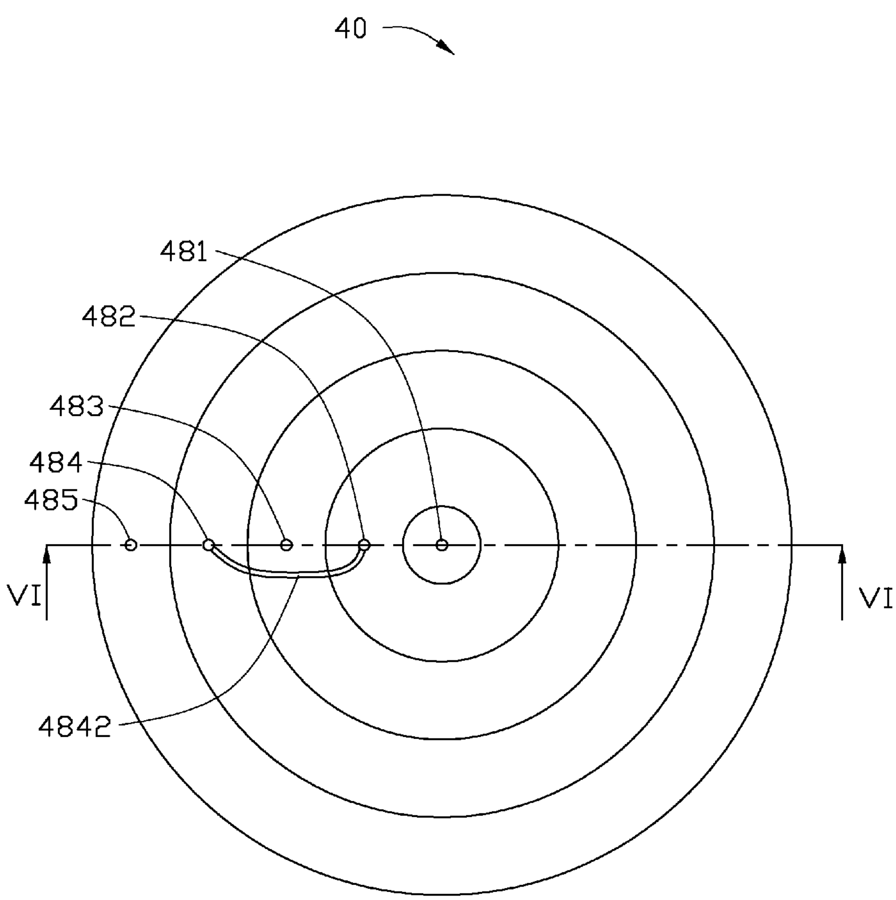


FIG. 5

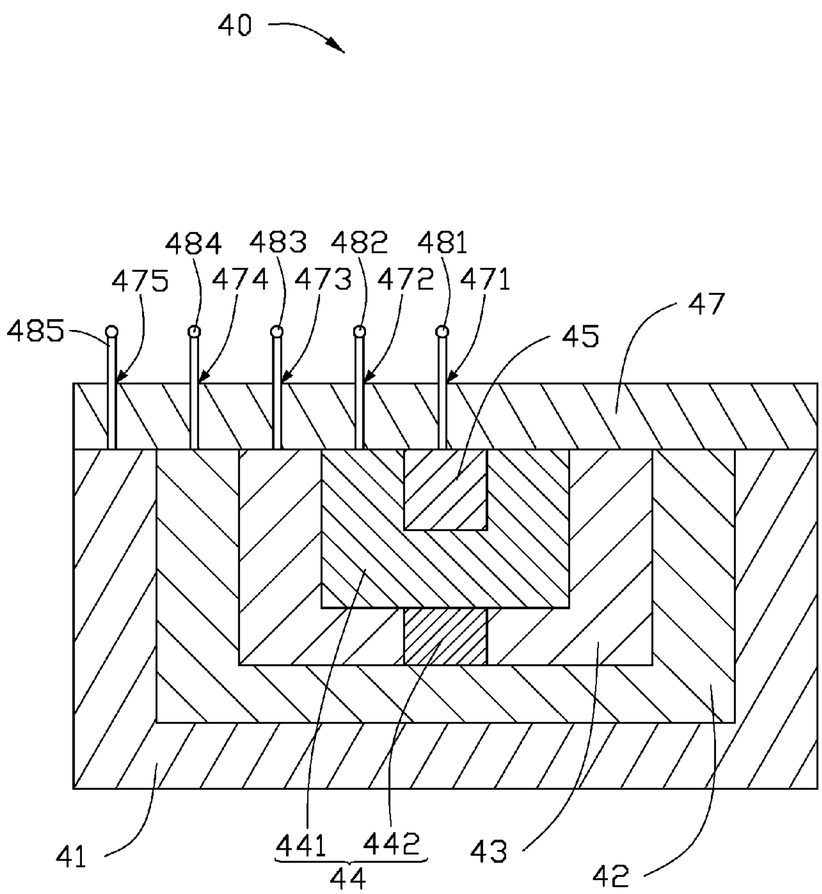

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FIG. 6

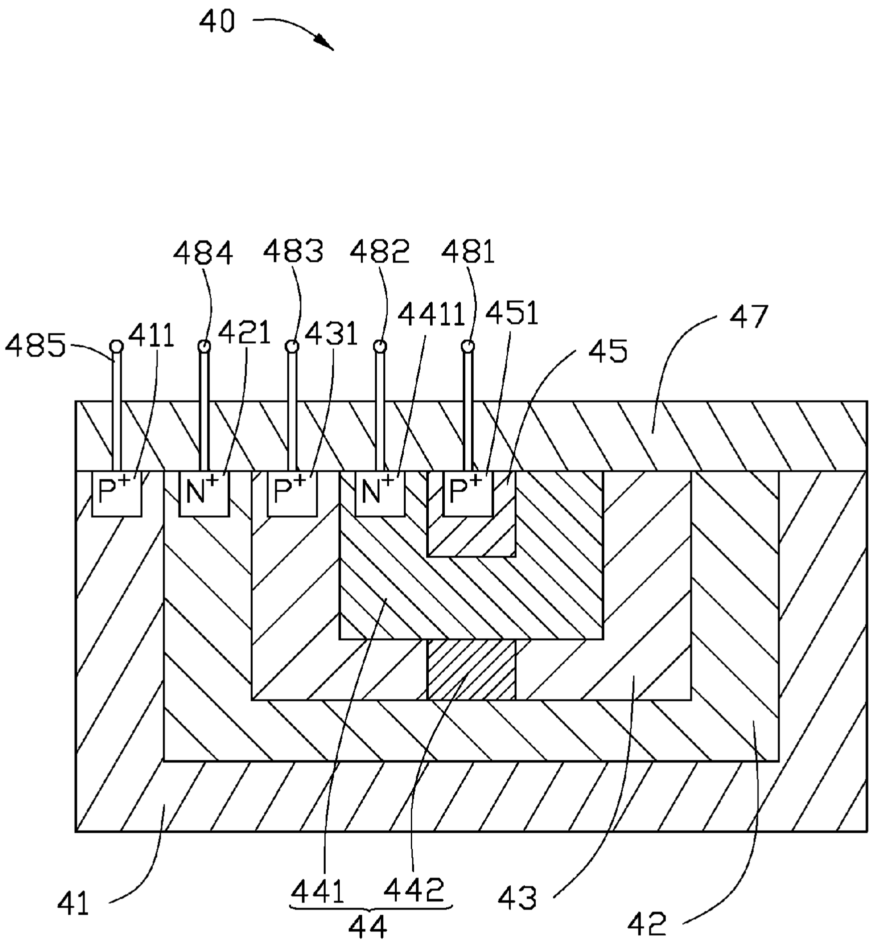

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FIG. 7

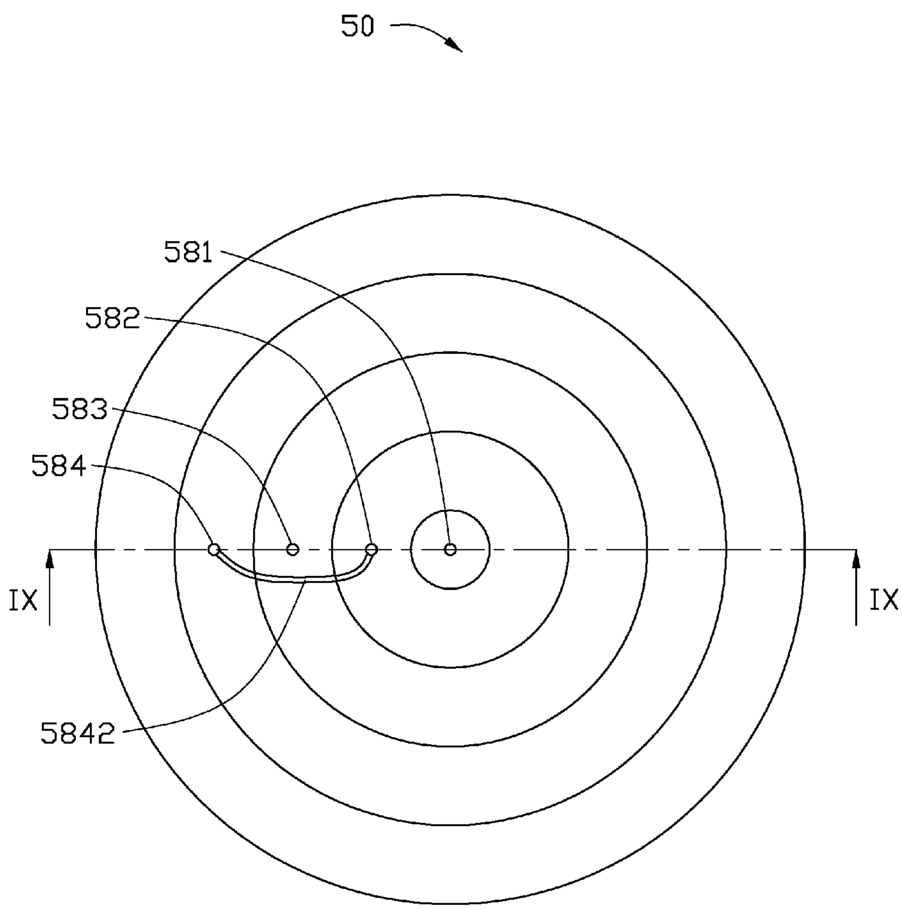

FIG. 8

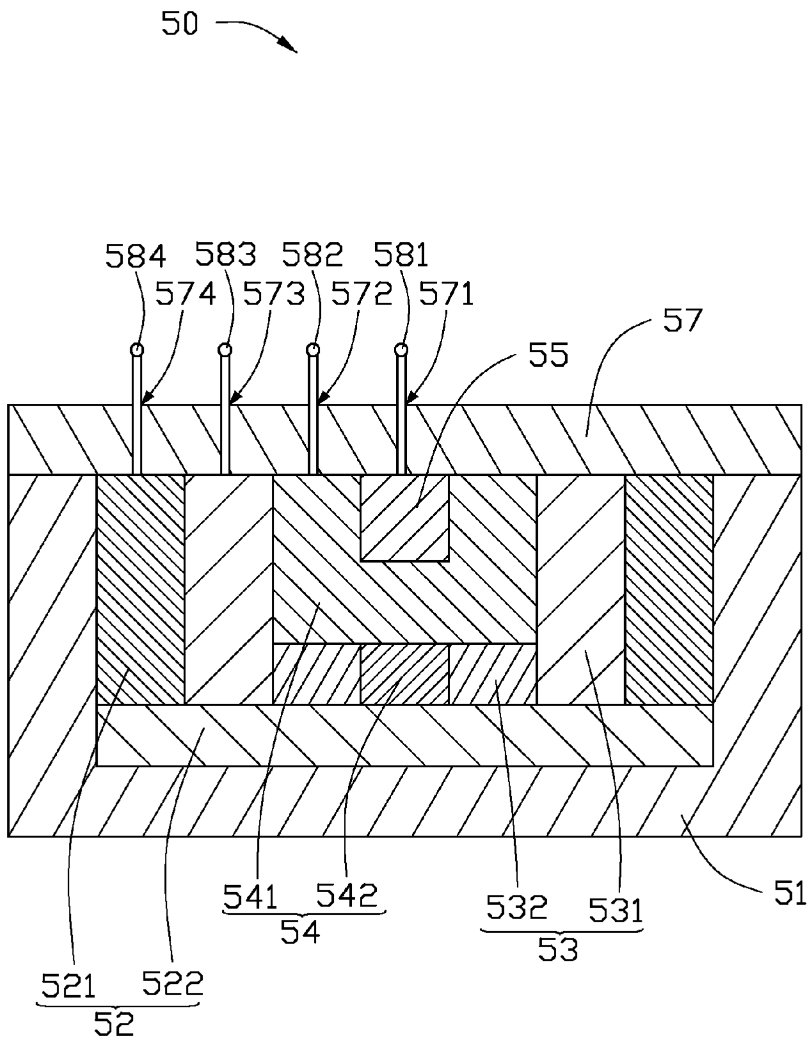
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FIG. 9

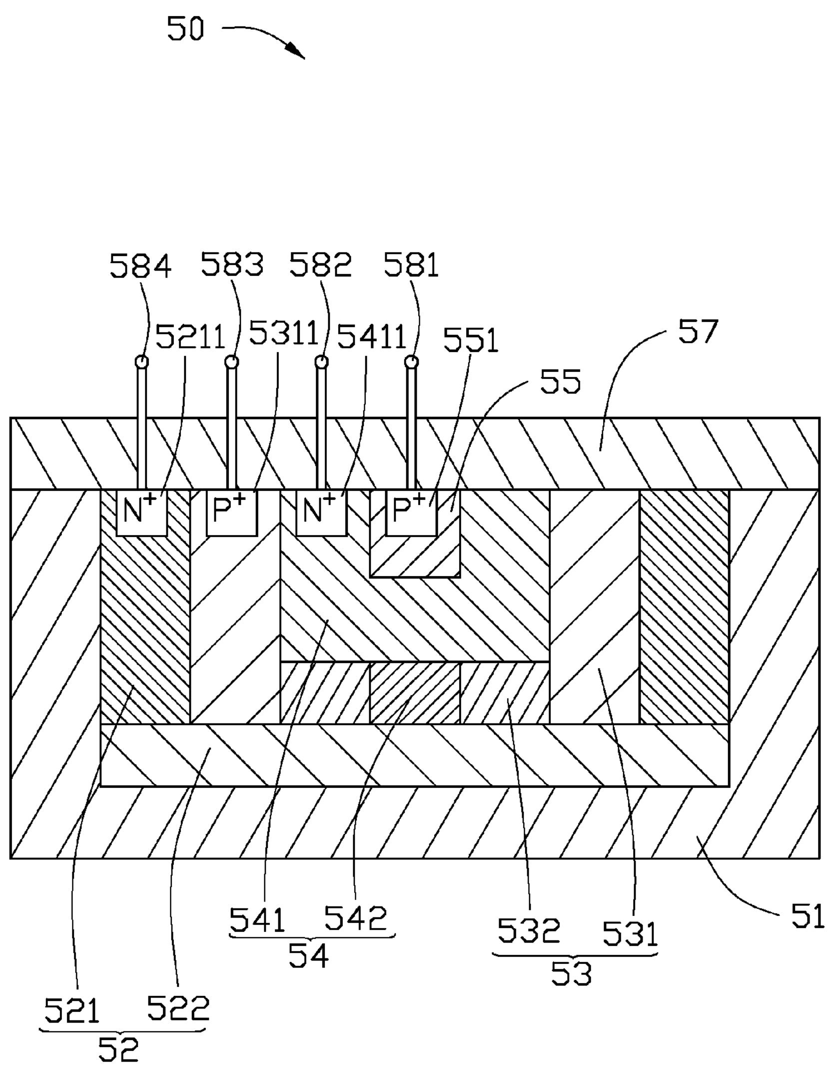
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FIG. 10

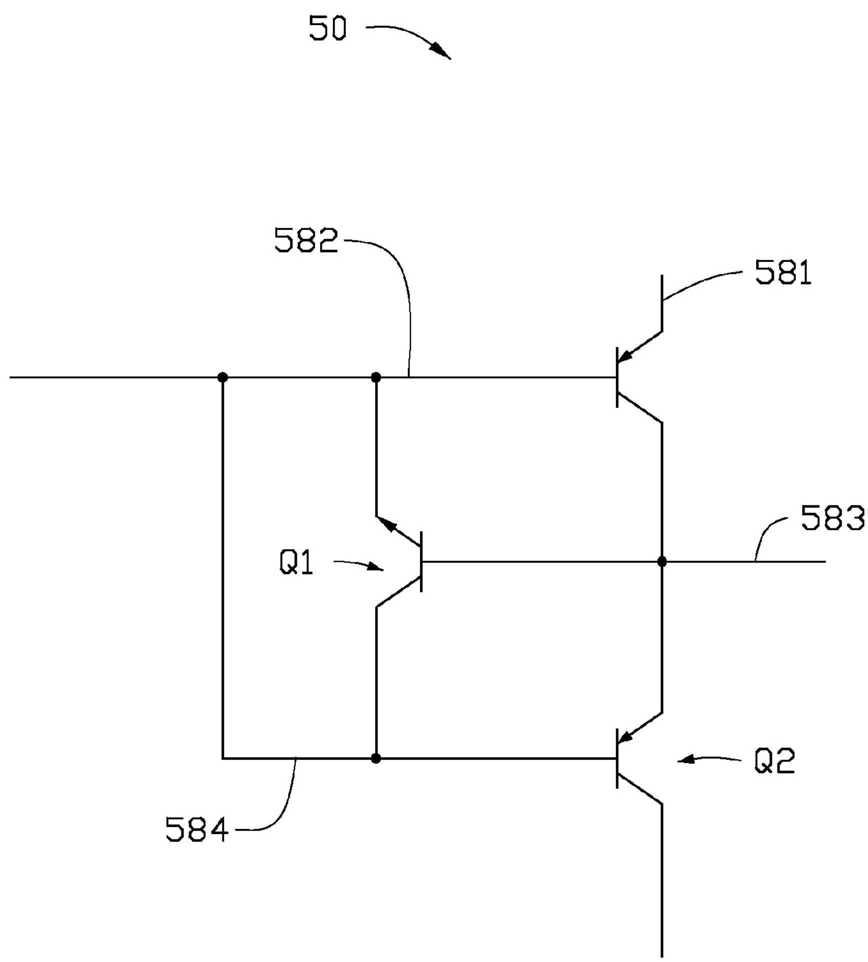

FIG. 11

TRIODE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to Taiwanese Patent Application No. 102135238 filed on Sep. 30, 2013, the contents of which are incorporated by reference herein.

FIELD

The subject matter herein generally relates to a triode.

BACKGROUND

A triode is an electronic amplifying element. In manufacturing processes of the triode, a parasitic triode is generated. A leak current is generated between an emitter of the parasitic triode and a collector of the parasitic triode which can damage the triode.

BRIEF DESCRIPTION OF THE DRAWINGS

Implementations of the present technology will now be described, by way of example only, with reference to the attached figures.

FIG. **1** is a plan view of a triode according to one embodiment of the present disclosure.

FIG. **2** is a cross-sectional view of the triode according to a first embodiment of FIG. **1** along line II-II.

FIG. **3** is a cross-sectional view of the triode according to a second embodiment of FIG. **1** along line II-II.

FIG. **4** is an equivalent circuit diagram of the triode of FIG. **1**.

FIG. **5** is a plan view of a triode according to another exemplary embodiment of the present disclosure.

FIG. **6** is a cross-sectional view of the triode according to a first embodiment of FIG. **5** along line VI-VI.

FIG. **7** is a cross-sectional view of the triode according to a second embodiment of FIG. **5** along line VI-VI.

FIG. **8** is a plan view of a triode according to another embodiment of the present disclosure.

FIG. **9** is a cross-sectional view of the triode according to a first embodiment of FIG. **8** along line IX-IX.

FIG. **10** is a cross-sectional view of the triode according to a second embodiment of FIG. **8** along line IX-IX.

FIG. **11** is an equivalent circuit diagram of the triode of FIG. **8**.

DETAILED DESCRIPTION

It will be appreciated that for simplicity and clarity of illustration, where appropriate, reference numerals have been repeated among the different figures to indicate corresponding or analogous elements. In addition, numerous specific details are set forth in order to provide a thorough understanding of the embodiments described herein. However, it will be understood by those of ordinary skill in the art that the embodiments described herein can be practiced without these specific details. In other instances, methods, procedures, and components have not been described in detail so as not to obscure the related relevant feature being described. The drawings are not necessarily to scale and the proportions of certain parts may be exaggerated to better illustrate details and features. The description is not to be considered as limiting the scope of the embodiments described herein.

The term "coupled" is defined as connected, whether directly or indirectly through intervening components, and is not necessarily limited to physical connections. The connection can be such that the objects are permanently connected or releasably connected.

FIG. **1** illustrates a plan view of a triode **30**. FIG. **2** illustrates a cross-sectional view of the triode **30** along line II-II. The triode **30** can include a semiconductor substrate **31**, a deep n-well **32**, a p-well **33**, an n+ doping region **34**, and a p+ doping region **35**. In the embodiment, the semiconductor substrate **31** is of p-type conductivity. The deep n-well **32** is included in the semiconductor substrate **31**. The p-well **33** is disposed adjacent to the deep n-well **32**. The n+ doping region **34** is formed by heavily doping n-type impurities in the p-well **33**. The p+ doping region **35** is formed by heavily doping p-type impurities in the n+ doping region **34**.

In the embodiment, the p+ doping region **35** serves as an emitter region of the triode **30**. The n+ doping region **34** serves as a base region of the triode **30**. The p-well **33** serves as a collector region of the triode **30**. In the embodiment, the p+ doping region **35**, the n+ doping region **34**, the p-well **33**, the deep n-well **32**, and the semiconductor substrate **31** are arranged in an annular structure. The p+ doping region **35** is located in a center of the annular structure and the semiconductor substrate **31** is located outside of the annular structure.

The triode **30** can further include a protection layer **37**. The protection layer **37** covers a surface of the triode **30** to protect the triode **30**. In the embodiment, the protection layer **37** is made of silicon oxide. A first opening hole **371** is defined in the protection layer **37** corresponding to the p+ doping region **35**. A first metal wire **381** extends from the first opening hole **371** to receive an emitter voltage. A second opening hole **372** is defined in the protection layer **37** corresponding to the n+ doping region **34**. A second metal wire **382** extends from the second opening hole **372** to receive a base voltage. A third opening hole **373** is defined in the protection layer **37** corresponding to the p-well **33**. A third metal wire **383** extends from the p-well **33** to receive a collector voltage. A fourth opening hole **374** is defined in the protection layer **37** corresponding to the deep n-well **32**. A fourth metal wire **384** extends from the fourth opening hole **374** to couple to the second metal wire **382** via a metal interconnect **3842**. A fifth opening hole **375** is defined in the protection layer **37** corresponding to the semiconductor substrate **31**. A fifth metal wire **385** extends from the fifth opening hole **375** to receive a substrate voltage. In the embodiment, the fifth metal wire **385** is grounded. In the embodiment, the second metal wire **382**, the fourth metal wire **384**, and the meal interconnect **3842** serve as a conducting channel to electrically connect to the n+ doping region **34** and the deep n-well **32**.

FIG. **3** illustrates a cross-sectional view of the triode **30** according to a second embodiment. The triode **30** can further include an emitter contact region **351** by doping p-type impurities. The emitter contact region **351** contains a higher doping concentration than that of the p+ doping region **35** to decrease a contact resistance between the first metal wire **381** and the p+ doping region **35**. The triode **30** can further include a base contact region **341** by doping n-type impurities. The base contact region **341** contains a higher doping concentration than that of the n+ doping region **34** to decrease a contact resistance between the second metal wire **382** and the n+ doping region **34**. The triode **30** can further include a collector contact region **331** by doping p-type impurities. The collector contact region **331** contains a higher doping concentration than that of the p-well **33** to decrease a contact resistance between the third metal wire **383** and the p-well **33**. The triode **30** can further include an n-well contact region **321** by doping n-type impurities. The n-well contact region **321** contains a higher doping concentration than that of the deep n-well **32** to decrease a contact resistance between the fourth metal wire **384** and the deep n-well **32**. The triode **30** can further include substrate contact region **311** by doping p-type impurities. The substrate contact region **311** contains a higher doping concentration than that of the semiconductor substrate **31** to decrease a contact resistance between the fifth metal wire **385** and the semiconductor substrate **31**.

FIG. **4** illustrates an equivalent circuit diagram of the triode **30**. The triode **30** can include a first parasitic NPN triode Q**1** and a second parasitic PNP triode Q**2**. The first parasitic NPN triode Q**1** is formed by the n+ doping region **34**, the p-well **33** and the deep n-well **32**. The n+ doping region **34** serves as an emitter region of the first parasitic NPN triode Q**1**, the p-well **33** serves as a base region of the first parasitic NPN triode Q**1**, and the deep n-well **32** serves as a collector region of the first parasitic NPN triode Q**1**. The second parasitic NPN triode Q**2** is formed by the p-well **33**, the deep n-well **32**, and the semiconductor substrate **31**. The p-well **33** serves as an emitter region of the second parasitic PNP triode Q**2**, the deep n-well **32** serves as a base region of the second parasitic PNP triode Q**2**, and the semiconductor substrate **31** serves as a collector region of the second parasitic PNP triode Q**2**.

The emitter region of the first parasitic PNP triode Q**1** is coupled to the base region of the triode **30** via the second metal wire **382**. The base region of the first parasitic PNP triode Q**1** is coupled to the collector region of the triode **30** and the emitter region of the second parasitic PNP triode Q**2** via the third metal wire **383**. The collector region of the first parasitic PNP triode Q**1** is coupled to the emitter region of the second parasitic PNP triode Q**2** and the emitter region of the first parasitic PNP triode Q**1** via the fourth metal wire **384**. The collector region of the second parasitic PNP triode Q**2** is grounded.

In the embodiment, the second metal wire **382** is coupled to the fourth metal wire **384** via the metal interconnect **3842**, thus the deep n-well **32** is coupled to the n+ doping region **34**, and the deep n-well **32** and the n+ doping region **34** receive the base voltage. A breakdown of the deep n-well **32**, the n+ doping region **34** and the p-well **33** can be avoided.

FIG. **5** illustrates a plan view of a triode **40** according to another exemplary embodiment of the present disclosure. FIG. **6** illustrates a cross-sectional view of the triode **40** according to a first embodiment. The triode **40** can include a semiconductor substrate **41**, a deep n-well **42**, a p-well **43**, an n+ doping region **44**, and a p+ doping region **45**. In the embodiment, the semiconductor substrate is of p-type conductivity. The n+ doping region **44** can include a main body **441** and a connection body **442**. The connection body **442** is located in the p-well **43** to divide the p-well **43**. The connection body **442** is coupled between the deep n-well **42** and the main body **441**. The deep n-well **42** is included in the semiconductor substrate **41**. The p-well **43** is disposed adjacent to the deep n-well **42**. The n+ doping region **44** is formed by heavily doping n-type impurities in the p-well **43**. The p+ doping region **45** is formed by heavily doping p-type impurities in the n+ doping region **44**.

In the embodiment, the p+ doping region **45** serves as an emitter region of the triode **40**. The n+ doping region **44** serves as a base region of the triode **40**. The p-well **43** serves as a collector region of the triode **40**. In the embodiment, the p+ doping region **45**, the n+ doping region **44**, the p-well **43**, the deep n-well **42**, and the semiconductor substrate **41** are arranged in an annular structure. The p+ doping region **45** is located in a center of the annular structure and the semiconductor substrate **41** is located outside of the annular structure.

The triode **40** can further include a protection layer **47** covering a surface of the triode **40** to protect the triode **40**. In the embodiment, the protection layer **47** is made of silicon oxide. A first opening hole **471** is defined in the protection layer **47** corresponding to the p+ doping region **45**. A first metal wire **481** extends from the first opening hole **471** to receive an emitter voltage. A second opening hole **472** is defined in the protection layer **47** corresponding to the n+ doping region **44**. A second metal wire **482** extends from the second opening hole **472** to receive a base voltage. A third opening hole **473** is defined in the protection layer **47** corresponding to the p-well **43**. A third metal wire **483** extends from the p-well **43** to receive a collector voltage. A fourth opening hole **474** is defined in the protection layer **47** corresponding to the deep n-well **42**. A fourth metal wire **484** extends from the fourth opening hole **474** to couple to the second metal wire **482** via a metal interconnect **4842**. A fifth opening hole **475** is defined in the protection layer **47** corresponding to the semiconductor substrate **41**. A fifth metal wire **385** leads from the fifth opening hole **475** to receive a substrate voltage. In the embodiment, the fifth metal wire **385** is grounded.

In the embodiment, the second metal wire **482**, the fourth metal wire **484**, and the meal interconnect **4842** serve as a first conducting channel to electrically connect to the n+ doping region **44** and the deep n-well **42**. The connection body **442** serves as a second conducting channel to electrically connected to the n+ doping region **44** and the deep n-well **42**.

In another embodiment, the fourth opening hole **474** and the fourth metal wire **482** are omitted and the main body **441** is coupled to the deep n-well **42** via the connection body **442**. The connection body **442** is formed by doping n-type impurities in the p-well **43**. The connection body **442** is of higher doping concentration than the deep n-well **42** and lower doping concentration than the main body **441**.

FIG. **7** illustrates a cross-sectional view of the triode **40** according to a second embodiment. The triode **40** can further include an emitter contact region **451** by doping p-type impurities. The emitter contact region **451** contains a higher doping concentration than that of the p+ doping region **45** to decrease a contact resistance between the first metal wire **381** and the p+ doping region **45**. The triode **40** can further include a base contact region **4411** by doping n-type impurities. The base contact region **4411** contains a higher doping concentration than that of main body **441** to decrease a contact resistance between the second metal wire **482** and the main body **441**. The triode **40** can further include a collector contact region **431** by doping p-type impurities. The collector contact region **431** contains a higher doping concentration than that of the p-well **43** to decrease a contact resistance between the third metal wire **483** and the p-well **43**. The triode **40** can further include a substrate contact region **411** by doping p-type impurities. The substrate contact region **411** contains a higher doping concentration than that of the semiconductor substrate **41** to decrease a contact resistance between the fifth metal **485** and the semiconductor substrate **41**.

An equivalent circuit of the triode **40** is similar to the equivalent circuit of the triode **30**.

FIGS. **8-11** illustrate that a triode **50** can include a semiconductor substrate **51**, a deep n-well **52**, a p-well **53**, an n+ doping region **54**, and a p+ doping region **55**. In the embodiment, the semiconductor substrate is of p-type conductivity. The n+ doping region **54** can include a main body **541** and a connection body **542**. The connection body **542** is located at the p-well **53** to divide the p-well **53**. The connection body **542** is coupled between the deep n-well **52** and the main body **541**. The p-well **53** can include a first portion **531** and a second portion **532**. The second portion **532** is located between the connection body **542** and the first portion **531**. The first portion **531** contains a higher doping concentration than that of the second portion **532** to decrease a contact between the collector region and the base region of the triode **50**.

The deep n-well **52** can include a first well portion **521** and a second well portion **522**. The first well portion **521** and the connection body **542** are located on the second well portion **522**. The first well portion **521** is disposed outside of the first portion **531**. The first well portion **521** contains a lower doping concentration than that of the second well portion **522**. In the embodiment, the second well portion **522** is an N-buried layer.

The triode **50** can further include a protection layer **57** covering a surface of the triode **50** to protect the triode **50**. In the embodiment, the protection layer **57** is made of silicon oxide. A first opening hole **571** is defined in the protection **57** corresponding to the p+ doping region **55**. A first metal wire **581** extends from the first opening hole **571** to receive an emitter voltage. A second opening hole **572** is defined in the protection layer **57** corresponding to the n+ doping region **54**. A second metal wire **582** extends from the second opening hole **572** to receive a base voltage. A third opening hole **573** is defined in the protection layer **57** corresponding to the p-well **53** to receive a collector voltage. A fourth opening hole **574** is defined in the protection layer **57** corresponding to the deep n-well **52** to couple to the second metal wire **582** via a metal interconnect **5842**.

The connection body **542** serves as a conducting channel to electrically connected to the main body **541** and the deep n-well **52**. In another embodiment, the fourth opening hole **574** and the fourth metal wire **582** are omitted. The connection body **542** is formed by doping n-type impurities in the p-well **53**. The connection body **542** is of higher doping concentration than the deep n-well **52** and lower doping concentration than the main body **541**.

FIG. **10** illustrates a cross-sectional view of the triode **50** according to a second embodiment along line IX-IX. The triode **50** is similar to the triode of FIG. **9** except that the triode **50** can further include an emitter contact region **551**, a base contact region **5411**, a collector contact region **5311**, and a well contact region **5211**. The emitter contact region **551** is formed by doping p-type impurities. The emitter contact region **551** contains a higher doping concentration than that of the p+ doping region **55** to decrease a contact resistance between the first metal wire **581** and the p+ doping region **55**. The base contact region **5411** is formed by doping n-type impurities. The base contact region **5411** contains a higher doping concentration than that of the main body **541** to decrease a contact resistance between the second wire **582** and the first portion **531** of the p-well **53**. The collector contact region **531** is formed by doping p-type impurities. The collector contact region **531** contains a higher doping concentration than that of the first portion **531** of the p-well **53** to decrease a contact resistance between the third metal wire **583** and the p-well **53**. The well contact region **5211** contains a higher doping concentration than that of the first well portion **521** of the deep n-well to decrease a contact resistance between the fourth metal **584** and the deep n-well.

An equivalent circuit of the triode **50** as shown in FIG. **11** is similar to the equivalent circuit of the triode **30** except that the collector of the second parasitic PNP triode Q**2** is floating.

It is to be understood that even though numerous characteristics and advantages of the present embodiments have been set forth in the foregoing description, with details of the structures and functions of the embodiments, the disclosure is illustrative only. Changes may be made in the details, especially in the matter of arrangement of parts within the principles of the embodiments, to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

What is claimed is:

1. A triode, comprising:

a semiconductor substrate;

a deep n-well adjacent to the semiconductor substrate;

a p-well serving as a collector region of the triode;

an n+ doping region serving as a base region of the triode;

a p+ doping region serving as an emitter region of the triode; and

at least one conducting channel electrically connected to the deep n-well and the n+ doping region;

wherein a first metal wire extends from the p+ doping region to receive an emitter voltage, a second metal wire extends from the n+ doping region to receive a base voltage, a third metal wire extends from the p-well to receive a collector voltage, and a fourth metal wire extends from the deep n-well to receive the emitter voltage; and the second metal wire is coupled to the fourth metal wire via a metal interconnect arranged outside of the p-well; the second metal wire, the fourth metal wire and the metal interconnect serve as a first conducting channel electrically connected to the deep n-well and the n+ doping region; and

an emitter contact region, a base contact region, a collector contact region, and a well contact region, the emitter contact region contains a higher doping concentration than that of the p+ doping region, the base contact region contains a higher doping concentration than that of the n+ doping region, the collector contact region contains a higher doping concentration than that of the p-well, and the well contact region contains a higher doping concentration than that of the deep n-well.

2. A triode comprising:

a semiconductor substrate;

a deep n-well adjacent to the semiconductor substrate;

a p-well serving as a collector region of the triode;

an n+ doping region serving as a base region of the triode;

a p+ doping region serving as an emitter region of the triode; and

at least one conducting channel electrically connected to the deep n-well and the n+ doping region;

wherein a first metal wire extends from the p+ doping region to receive an emitter voltage, a second metal wire extends from the n+ doping region to receive a base voltage, a third metal wire extends from the p-well to receive a collector voltage, and a fourth metal wire extends from the deep n-well to receive the emitter voltage;

wherein the n+ doping region comprises a main body and connection body, and the connection body is located in the p-well to divide the p-well and coupled between the deep n-well and the main body, the connection body serves as a first conducting channel electrically connected to the deep n-well and the n+ doping region.

3. The triode of claim **2**, wherein the p-well comprises a first portion and a second portion located between the connection body and the first portion and the first portion contains a higher doping concentration than that of the second portion.

4. The triode of claim **2**, wherein the deep n-well comprises a first well portion and a second well portion, the first well portion and the connection body are located on the second well portion, the first well portion is disposed outside of the first portion, and the first well portion contains a lower doping concentration than that of the second well portion.

5. A triode, comprising:

a semiconductor substrate with a first conductivity;

a deep well with a second conductivity included in the semiconductor substrate;

a lightly doping region with the first conductivity serving as a collector region of the triode and included in the deep well;

a first highly doping region with the second conductivity serving as a base region of the triode and included in the p-well;

a second highly doping region with the first conductivity serving as an emitter region of the triode; and

at least one conducting channel electrically connected to the deep well and the first highly doping region;

wherein a first metal wire extends from the second highly doping region to receive an emitter voltage, a second metal wire extends from the first highly doping region to receive a base voltage, a third metal wire extends from the lightly doping region to receive a collector voltage, and a fourth metal wire extends from the deep well to receive the emitter voltage, and the second metal wire is coupled to the fourth metal wire via a metal interconnect arranged outside of the lightly doping region; the second metal wire, the fourth metal wire and the metal interconnect serve as a first conducting channel electrically connected to the deep n-well and the first highly doping region; and

wherein the first highly doping region comprises a main body and connection body, and the connection body is located in the lightly doping region to divide the lightly doping region and coupled between the deep well and the main body, the connection body serves as a second conducting channel electrically connected to the deep well and the first highly doping region.

6. The triode of claim **5**, wherein the lightly doping region comprises a first portion and a second portion located between the connection body and the first portion and the first portion contains a higher doping concentration than that of the second portion.

7. The triode of claim **5**, wherein the deep well comprises a first well portion and a second well portion, the first well portion and the connection body are located on the second well portion, the first well portion is disposed outside of the first portion, and the first well portion contains a lower doping concentration than that of the second well portion.

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